

## Mapping the global digital discourse on nutraceuticals: a two-year hashtag analysis of the X platform (formerly T witter)

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**Engagement with nutritional health information through digital platforms has become increasingly important for market trends and public health communication. This study examined posts containing the terms “nutraceutical” or “nutraceuticals” shared on X (formerly Twitter) over a 24-month period from 1 August 2023 to 1 August 2025. Data collection and analysis were conducted using the Fedica platform analytics, completed on 22 August 2025. The dataset comprises 82,804 individual posts from 61,527 unique user accounts, with a total of 19,348,499 impressions. Posts originated from 170 countries, with the USA contributing 55.93% of the activity, followed by India (20.01%), and Canada (4.03%). Lexical analysis identified stem cells, peptides, and psychedelics as the most prevalent terms, whereas hashtag co-occurrence analysis highlighted key themes related to health, wellness, manufacturing, pharmaceuticals, and nutritional content. Discussions about nutraceuticals have focused on specific compounds, such as cannabidiol (CBD; n=1,211), nattokinase (n=923), and protein extracts (n=596). The posts demonstrated a high potential for amplification, averaging 234 impressions per post, indicating a strong capacity for information dissemination. This analysis reveals that discussions on the X platform on nutraceutical products form a globally distributed communication network with concentrated user participation from economically developed regions and major emerging markets. The findings underscore the role of the X platform as a key channel for exchanging dietary supplement information and emphasise considerations for stakeholders in nutritional product marketing, health communication, and regulatory oversight.**

**KEYWORDS:** social media / dietary supplements / digital health communication / content analysis / cannabidiol / nattokinase

Nutraceuticals, positioned at the intersection of nutrition and pharmaceuticals, provide both nutritional and therapeutic benefits and play a significant role in disease prevention and health promotion [Santini 2022, Ashrafpour and Ashrafpour 2025]. The global market for nutraceuticals and dietary supplements has witnessed rapid growth, with a valuation of USD 463.5 billion in 2025 and a projected increase to USD 762.3 billion by 2035, indicating a Compound Annual Growth Rate (CAGR) of 5.1% [Future Market Insights 2025]. Rising health consciousness, ageing populations, the prevalence of chronic diseases, and a global shift towards preventive healthcare and personalised nutrition drive this expansion. Encompassing functional foods, dietary supplements, and beverages enriched with bioactive components such as polyphenols, omega-3 fatty acids, herbal extracts, and probiotics, nutraceuticals demonstrate potent antioxidant and anti-inflammatory properties that mitigate oxidative stress, regulate cytokine production, and alleviate chronic inflammation associated with cardiovascular, metabolic, and neurodegenerative diseases [Yeung *et al.* 2020a, 2021a, Bartel *et al.* 2024, Vignesh *et al.* 2024, Rao 2025]. This sector is progressing through AI-driven formulations, nano-based enhancements in bioavailability, and more stringent evidence-based regulatory standards to ensure safety and efficacy [Shah *et al.* 2024].

Digital communication has transformed due to mobile connectivity and platform expansion, altering how consumers access health information [Jia *et al.* 2021, Lim *et al.* 2022]. Social media platforms now rival traditional search engines for health information, with 66% of young adults using social media [Stifjell *et al.* 2025]. These demographic groups view social media as a reliable source, often considering it more trustworthy than official health organisations because of parasocial relationships with content creators and peers [Pfender and Bleakley 2024, Rong *et al.* 2025]. TikTok, YouTube, Instagram, and LinkedIn appeal to this cohort through rapid information sharing, hashtag organization, real-time interaction, and demographic engagement [Lim *et al.* 2022, Nawaz *et al.* 2023, Chandragiri *et al.* 2025, Rosamystica *et al.* 2025]. The X platform (formerly Twitter) enables health discussions through its structure, supporting informational content and active participation, making it valuable for applications such as exploring public health conversations, fostering empathy in healthcare communication, advancing open innovation in digital health, fostering global collaboration through biomedical hashtag campaigns, and highlighting the importance of patient-family engagement during crises [Kletecka-Pulker *et al.* 2021, Rosamystica *et al.* 2025]. Analysing hashtags provides a systematic approach to evaluate conversation volume, demographics, themes, and engagement patterns, offering an analytical method for investigating health topics such as cardiovascular disease awareness, nutritional information accuracy, health communication campaigns and public responses to global health crises [Sutton *et al.* 2018, Mondal *et al.* 2022, Singla *et al.* 2023, Arshad *et al.* 2024, Rosamystica *et al.* 2025]. This framework helps to understand how digital platforms influence public health discussions, with evidence showing that platform design, user interfaces, interactive features, content source credibility, and inclusiveness affect young adults' health information-seeking

behaviours and information trustworthiness perception [Pfender and Bleakley 2024, Rong *et al.* 2025, Stifjell *et al.* 2025].

Nutraceutical products, including dietary supplements, functional foods, and bioactive compounds, are integral to consumer wellness practices and present significant market opportunities [Angotti and Fields 2023, Matin *et al.* 2024a, 2025a]. However, the quality of nutraceutical information on digital platforms remains poorly understood [Denniss *et al.* 2024]. As consumers rely on social media for supplementary information, they face risks, including unverified claims, unsupported health assertions, and promotional content driven by commercial interests that lack scientific validation [Denniss *et al.* 2024; Zarei *et al.* 2025]. Investigating nutraceutical discussions on platforms such as X provides essential data for public health professionals, regulatory bodies, and health communication specialists who aim to ensure information quality and protect consumers from misinformation [Denniss *et al.* 2024].

Despite the global nutraceutical market and the role of social media as a primary health information source, systematic analysis of nutraceutical-related discussions on X remains absent from the current literature. The X platform was chosen for analysis owing to its open data access, persistent hashtag culture, and established application in public health surveillance research. In contrast to visually oriented platforms, X enables rapid dissemination of text-based information, expert commentary, and industry communication, rendering it particularly suitable for large-scale lexical and hashtag analyses. This study examined the volume, distribution, themes, and content patterns of X posts containing “nutraceutical” and “nutraceuticals” terms over a period of 24 months. This study aims to assess the posting frequency and level of engagement, identify geographical origins of users sharing nutraceutical content, determine products and categories most frequently mentioned, analyse co-occurring hashtags to identify thematic connections, and examine the most retweeted content to understand engagement drivers.

## **Material and methods**

### **Data collection strategy**

X posts containing “nutraceutical” or “nutraceuticals” were systematically collected over 24 months (from 1 August 2023 to 1 August 2025). Data collection and analysis were conducted using the Fedica platform analytics tools (<https://fedica.com/>) on 22 August 2025. The Fedica analytics environment enables the historical archiving of public social media content and extracts engagement metrics, including post numbers, user counts, and total impressions, based on specified search criteria and timeframes. During collection, no predetermined inclusion or exclusion criteria were applied, and all posts containing the target terminology within the specified period were included in the dataset. This approach includes original tweets, retweets, and replies featuring “nutraceutical” or “nutraceuticals” terminology, enabling an unfiltered examination of discourse patterns. All data were publicly available,

anonymised, and collected in compliance with the terms of service of the X platform; therefore, ethical approval was not required.

#### **Data processing and computational analysis**

The data files were processed in Python 3 using the standard analytical libraries. The text content underwent preprocessing to normalise it, including removing URLs, retweet indicators, user mentions, special characters, normalising whitespace, and converting to lowercase. To identify significant vocabulary, the criteria excluded high-frequency words that lacked semantic value. A list of word frequencies was compiled, from which 40 common English words and 64 domain-specific terms were manually classified and excluded from analysis.

Following preprocessing, frequency counts for the remaining vocabulary were computed using the Python Counter class. A normalisation procedure consolidated morphologically similar terms that shared the same root. Hashtag elements are identified through regular expressions, focusing on sequences starting with a hash symbol. A comprehensive reference dictionary comprising 189 terms was developed and systematically categorised into the following groups: vitamins, minerals, omega-fatty acids, probiotics/prebiotics, proteins and amino acids, herbs and botanicals, medicinal mushrooms, specialty compounds, and general terminology. Nutraceutical terms were identified in posts using regex-based pattern matching with word boundary detection, whereas hashtags were extracted separately using regex patterns. Both analyses utilised case-insensitive matching, while preserving the original case for reporting purposes. Frequency distributions were calculated for general words, hashtags, and nutraceutical terms, and the 30 most frequent items in each category were exported for subsequent analysis and visualisation.

User locations were determined using the location metadata from X profiles and Fedica aggregated at the country level. To investigate temporal patterns, monthly post-counts were analysed throughout the observation period. The post frequency was determined on monthly and yearly bases. The highest activity periods were identified by ranking the monthly intervals. Descriptive statistics included the means, frequency counts, and percentile distributions. Minority groups were expressed as percentages of the overall values. No inferential statistical tests were conducted.

## **Results and discussion**

#### **Overall activity metrics and reach assessment**

Over a period of 24 months, 61,527 unique user accounts on the X platform disseminated 82,804 individual posts containing the specified nutraceutical terms. This activity culminated in a cumulative viewership of 19,348,499 impressions, which equated to an average of 234 views per post. The ratio of unique users to posts (61,527 users: 82,804 posts) indicated an average of 1.35 posts per user. This suggests that participation is distributed across a broad user base rather than concentrated among a few prominent accounts.

The analysis of the follower distribution among contributing users indicates diverse participation patterns across varying levels of account influence. Among the users analysed, 668 (1.08%) had no followers, whereas 10,083 accounts (16.38%) possessed fewer than 100 followers. The majority of participants were accounts with 100–1,000 followers, comprising 29,160 contributors (47.42%), indicating broad community participation (Fig. 1). Accounts with higher follower counts were less prevalent, with 18,946 accounts (30.82%) having between 1,000 and 10,000 followers, 1,987 accounts (3.23%) having between 10,000 and 50,000 followers, and 683 accounts (1.11%) having more than 50,000 followers.

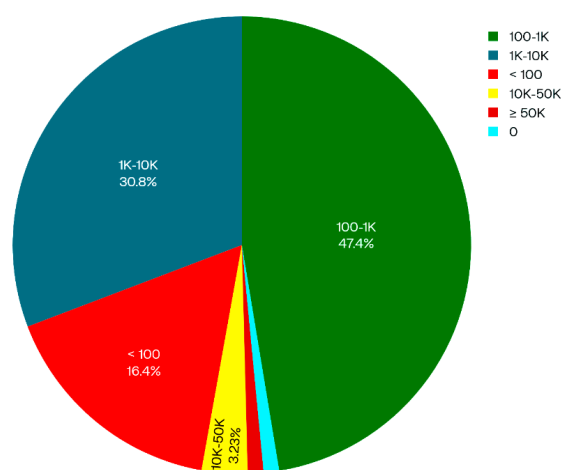


Fig. 1. Distribution of contributing users by follower count (n=61,527). Most participants maintained follower counts between 100 and 10,000, indicating broad community engagement rather than concentrated activities from high-influence accounts.

#### **Geographical distribution patterns**

User accounts from 170 distinct countries engaged in discussions concerning nutraceuticals on the X platform underscore a global level of participation. Nevertheless, the distribution of posting activities was predominantly concentrated in specific regions, with the three countries collectively responsible for 79.98% of all posts (Tab. 1). The United States emerged as the foremost contributor, generating 46,296 posts, constituting 55.93% of the total. India followed, albeit with a notable disparity, contributing 16,566 posts (20.01%), whereas Canada ranked third with 3,340 posts (4.03%). Other countries exhibited significantly lower levels of participation, with the United Kingdom in fourth place contributing only 2,439 posts (2.95%). Spain occupied the fifth position with 1,539 posts (1.86%), and each of the remaining countries individually accounted for less than 1.86% of the total posts.

The top 20 countries in terms of post volume were the United States (USA), India, Canada, the United Kingdom (UK), Spain, Uganda, Australia, Switzerland,

**Table 1.** Geographical distribution of nutraceutical-related posts on X platform by country (top 20 countries). The United States and India collectively accounted for 75.94% of all posts during the study period

Rank	Country	Number of Posts	Percentage (%)
1	USA	46296	55.93
2	India	16566	20.01
3	Canada	3340	4.03
4	UK	2439	2.95
5	Spain	1539	1.86
6	Uganda	1349	1.63
7	Australia	1029	1.24
8	Switzerland	738	0.89
9	Pakistan	668	0.81
10	France	650	0.79
11	Nigeria	540	0.65
12	Japan	529	0.64
13	Singapore	459	0.55
14	South Africa	457	0.55
15	Germany	439	0.53
16	UAE	371	0.45
17	China	327	0.4
18	Italy	311	0.38
19	Mexico	273	0.33
20	Netherlands	252	0.3

Pakistan, France, Nigeria, Japan, Singapore, South Africa, Germany, the United Arab Emirates (UAE), China, Italy, Mexico, and the Netherlands. A significant geographic concentration was observed, with North American participants (the United States and Canada combined) contributing 59.96% of all posts and South Asian participants (India and Pakistan combined) accounting for 20.82% of the total activity.

#### Lexical analysis results

Following the preprocessing and filtering stages, a frequency analysis of the post-text content identified the 30 most prevalent terms within the dataset (Tab. 2). The term “stem cells” emerged as the most frequent, appearing 36,458 times and constituting approximately 44% of all filtered words. “Peptides” closely followed with 36,457 instances, nearly equalling the frequency of “stem cells”, while “psychedelics” ranked third with 36,419 occurrences. These three terms were significantly more frequent than other words in the dataset. The term “nutraceutical”, which served as the primary search term for data collection, appeared in 29,487 posts, representing 35.62% of the total, indicating that most posts employed alternative terminology rather than the search term itself.

In addition to the frequently used terms, there was a significant increase in the diversity of vocabulary. The term “hazelnut” appeared in 5,597 posts, representing 6.76% of the total, while “supplements” was mentioned in 4,607 posts (5.57%), and “food” in 3,659 posts (4.42%). Discussions often included specific commodities, with

**Table 2.** The top 30 most frequently mentioned words in nutraceutical-related posts after pre-processing and stop-word removal (n=82,804 posts). Percentages were calculated relative to the total post-count

Rank	Word	Frequency	Percentage (%)
1	stem cells	36458	44.03
2	peptides	36457	44.03
3	psychedelics	36419	43.98
4	nutraceutical	29487	35.61
5	hazelnut	5597	6.76
6	supplements	4607	5.56
7	food	3659	4.42
8	oil	3302	3.99
9	sugar	2969	3.59
10	palm	2818	3.4
11	nutella	2800	3.38
12	pharmaceutica ls	2044	2.47
13	natural	1918	2.32
14	industry	1714	2.07
15	pharma	1678	2.03
16	vitamin	1631	1.97
17	drug	1624	1.96
18	India	1585	1.91
19	organics	1485	1.79
20	wellness	1438	1.74
21	dietary	1425	1.72
22	herbal	1424	1.72
23	hair	1362	1.64
24	global	1272	1.54
25	ingredients	1198	1.45
26	Kakie	1161	1.4
27	skin	1124	1.36
28	nutrition	1070	1.29
29	growth	1045	1.26
30	world	1011	1.22

“oil” appearing in 3,302 posts (3.99%), “sugar” in 2,969 posts (3.59%), and “palm” in 2,818 posts (3.41%). Furthermore, “Nutella”, a food manufacturer, was referenced in 2,800 posts (3.38%), suggesting that conversations related to the food industry or nutrition frequently included mentions of commercial products.

Terms associated with industry structure were frequently identified, with “pharmaceuticals” appearing in 2,044 posts (2.47%), “pharma” in 1,678 posts (2.03%), and “drug” in 1,624 posts (1.96%). Language pertaining to health and wellness included “wellness” in 1,438 posts (1.74%), “dietary” in 1,425 posts (1.72%), and “herbal” in 1,424 posts (1.72%). References to “India” were found in 1,585 posts (1.91%), underscoring India’s significant role in the production and consumer market for nutraceuticals. Mentions of product companies included “Kakie” (1,161 times; 1.40%), likely indicating the Kakie Organics nutraceutical manufacturer, and “organics” (1,485 times; 1.79%).

The terminology associated with health benefits included terms such as “wellness” (1,438 mentions), “skin” (1,124 mentions; 1.36%), “nutrition” (1,070 mentions; 1.29%), and “growth” (1,045 mentions; 1.26%). This suggests that consumer discussions are more concentrated on specific health applications and aesthetic outcomes than general health maintenance.

While the terms “stem cells,” “peptides,” and “psychedelics” were identified as the most frequently occurring lexical items, a contextual analysis revealed that these terms were predominantly employed within aspirational or promotional narratives rather than as direct references to approved nutraceutical ingredients. In numerous instances, these terms appeared in discussions that positioned nutraceuticals alongside emerging biomedical concepts, such as regenerative medicine, peptide therapeutics, and psychedelic-assisted mental health research. This suggests a rhetorical alignment with scientific innovation rather than a focus on established product composition.

#### **Hashtag co-occurrence analysis**

In the analysis of hashtag usage patterns, 30 hashtags were identified as the most prevalent among posts containing nutraceutical-related terms (Tab. 3). The hashtag #nutraceuticals appeared 4,793 times, constituting 5.79% of the posts, thereby emerging as the most frequently utilised category hashtag. Furthermore, #nutraceutical was identified in 1,582 posts, accounting for 1.91% of the total. Collectively, these nutraceutical-specific hashtags were present in 7.70% of all posts analysed.

Hashtags pertaining to health and wellness are also prevalent. Specifically, hashtag #health appeared in 657 posts (0.79%), #wellness in 444 posts (0.54%), #nutrition in 421 posts (0.51%), and #healthcare in 232 posts (0.28%). Collectively, these health-oriented hashtags constituted approximately 2.1% of all posts. Conversely, hashtags related to manufacturing and industry were also prominent, including #manufacturing (444 instances; 0.54%), #manufacturer (341 instances; 0.41%), #export (240 instances; 0.29%), and #thirdpartymanufacturing (238 instances; 0.29%). This suggests that a notable portion of the content is directed towards industry professionals and business networking, rather than discussions focused on consumer health.

Hashtags associated with specific health philosophies and cultural practices, such as #ayurvedic (appearing 317 times; 0.38%), underscore notable Indian user demographics and acknowledge the importance of Ayurvedic medicinal traditions and plant-based ingredients. Hashtags denoting particular product categories included #supplements (477 times; 0.58%), #vitamins (203 times; 0.25%), #dietary supplements (178 times; 0.22%), and #health supplements (241 times; 0.29%), collectively comprising approximately 1.3% of all posts.

The prevalence of CBD-related hashtags underscores the extensive discourse surrounding cannabis-derived products, with #CBD appearing in 225 posts (0.27%). Company-specific hashtags were also frequently used, such as #zodiacpharma (220 instances; 0.27%), #arvproducts (216 instances; 0.26%), #hivproducts (215 instances; 0.26%), and #kakiorganics (213 instances; 0.26%), indicating activities from

**Table 3.** The top 30 most frequently used hashtags co-occurred with nutraceutical terminology. Hashtags reflect diverse themes, including product categories, health applications, manufacturing, and traditional medicine systems

Rank	Hashtag	Frequency	Percentage (%)
1	#nutraceuticals	4793	5.79
2	#nutraceutical	1582	1.91
3	#pharmaceutical	694	0.84
4	#health	657	0.79
5	#supplements	477	0.58
6	#manufacturing	444	0.54
7	#wellness	444	0.54
8	#nutrition	421	0.51
9	#manufacturer	341	0.41
10	#ayurvedic	317	0.38
11	#pharmaceuticals	262	0.32
12	#medicine	254	0.31
13	#healthsupplements	241	0.29
14	#export	240	0.29
15	#thirdpartymanufacturing	238	0.29
16	#healthcare	232	0.28
17	#CBD	225	0.27
18	#zodiacpharma	220	0.27
19	#innovation	217	0.26
20	#arvproducts	216	0.26
21	#hivproducts	215	0.26
22	#kakieorganics	213	0.26
23	#cosmetics	211	0.25
24	#organic	210	0.25
25	#healthandwellness	207	0.25
26	#maheshbabu	206	0.25
27	#vitamins	203	0.25
28	#pharma	190	0.23
29	#coffee	180	0.22
30	#dietarysupplements	178	0.21

corporate social media accounts or promotional initiatives by organisations. Hashtags pertaining to aesthetic applications included #coffee (180 instances; 0.22%), whereas those associated with general wellness and lifestyle, such as #healthandwellness (207 instances) and #innovation (217 instances), reflected a broad spectrum of consumer interests.

#### Nutraceutical product terminology identification

Utilising computational analysis with the 189-term nutraceutical reference dictionary, specific dietary supplement ingredients were identified in the post-collection. CBD, a phytochemical derived from *Cannabis sativa*, is the most frequently mentioned nutraceutical, appearing in 1,211 posts (1.46%) (Tab. 4). Discussions surrounding the CBD reflect ongoing regulatory developments, market

**Table 4.** The top 30 most frequently mentioned nutraceutical compounds and product categories were identified using dictionary-based pattern matching. CBD is the most discussed compound, followed by nattokinase and protein-based supplements

Rank	Nutraceutical	Frequency	Percentage (%)
1	CBD	1211	1.46
2	Nattokinase	923	1.11
3	Extract (generic)	596	0.72
4	Protein	532	0.64
5	Antioxidants	512	0.62
6	Vitamin C	428	0.52
7	Hemp	383	0.46
8	Probiotics	353	0.43
9	Curcumin	284	0.34
10	Zinc	241	0.29
11	Turmeric	232	0.28
12	Ashwagandha	204	0.25
13	Magnesium	184	0.22
14	Collagen	169	0.2
15	Garlic	152	0.18
16	Resveratrol	149	0.18
17	Omega-3	144	0.17
18	Quercetin	134	0.16
19	Vitamin D	120	0.14
20	Functional Food	116	0.14
21	Nootropic	115	0.14
22	Berberine	110	0.13
23	Superfood	107	0.13
24	Amino Acids	100	0.12
25	Ginseng	92	0.11
26	Prebiotics	92	0.11
27	Glutathione	91	0.11
28	Iron	89	0.11
29	Calcium	89	0.11
30	Omega (generic)	84	0.1

expansion, and consumer interest in cannabis-based products across regions with varying legal frameworks. Nattokinase, an enzyme sourced from fermented soybeans, was referenced in 923 posts (1.11%), indicating consumer interest in its potential applications in haemostatic and cardiovascular health.

In 596 posts (0.72%), there were general references to extract-type products without specifying their individual components. Mentions of protein-containing products and formulations appeared in 532 posts (0.64%), suggesting widespread consumer interest in protein supplements for purposes such as fitness, strength enhancement, and clinical nutrition. Antioxidant compounds were discussed in 512 posts (0.62%), underscoring the dialogues concerning oxidative stress and disease prevention.

Within the dataset, Vitamin C was referenced in 428 instances (0.52%), and Vitamin D was mentioned in 120 instances (0.15%). The relatively infrequent

mention of specific vitamins, as opposed to general supplement terms, suggests that discussions regarding supplements predominantly occur at a broader categorical level rather than focusing on individual micronutrients. Regarding minerals, zinc was cited 241 times (0.29%) and magnesium 184 times (0.22%), underscoring their importance in human metabolism and disease prevention.

Mentions of botanical ingredients were also prevalent. Turmeric was referenced in 232 posts (0.28%), whereas curcumin, its active compound, appeared in 284 posts (0.34%). Collectively, they constituted 0.62% of the posts, indicating a notable interest in anti-inflammatory phytochemicals. Ashwagandha, an Ayurvedic herb traditionally employed to manage stress and anxiety, was mentioned in 204 posts (0.25%), underscoring the growing acceptance of traditional medicinal ingredients by Western consumers. Ginger, which is frequently discussed in both culinary and medicinal contexts [Matin *et al.* 2025b], has not been quantified separately. Garlic was mentioned in 152 posts (0.18%). In total, these botanical ingredients comprised approximately 1.6% of the posts. The public interest in botanical ingredients is consistent with the scientific attention to such ingredients, as evident from recent literature analyses [Matin *et al.* 2024b, Yeung *et al.* 2025].

The terms “probiotic” and “prebiotic” were mentioned in 353 posts (0.43%) and 92 posts (0.11%), respectively, collectively accounting for 0.54% of the posts. This suggests a notable consumer interest in microbiome health and digestive well-being.

Omega-3 polyunsaturated fatty acids were referenced in 144 posts, constituting 0.17% of the total. In contrast, broader discussions concerning omega types appeared in 84 posts (0.10 %). Collagen, a structural protein that has recently garnered substantial consumer interest owing to its benefits in skin health and joint support, was highlighted in 169 posts, representing 0.20%.

Among the specialized compounds and phytochemicals, resveratrol was referenced 149 times (0.18%), quercetin 134 times (0.16%), berberine 110 times (0.13%), and glutathione 91 times (0.11%), along with various other bioactive substances. Products derived from hemp featured in 383 posts (0.46%), highlighting their significance as a botanical source of CBD products and other hemp-based supplement formulations.

The term “functional food” was referenced in 116 posts (0.14%), while discussions concerning nootropic compounds, which are intended for cognitive enhancement, appeared in 115 posts (0.14%). Furthermore, the term “superfood” was used in 107 posts (0.13%). These instances reflect the distinct categories of consumer interest and marketing language employed in the supplement industry.

#### **Temporal distribution of posting activity**

Over the 24-month observation period, there were significant temporal variations in posting activity. A total of 82,804 posts were recorded during the study and distributed as follows: 7,393 posts between August and December 2023, 63,048 posts in 2024 (constituting 76.07% of the total), and 12,363 posts from January to August 2025.

Throughout the year, there were notable variations in monthly activity levels. October 2024 represented the peak period of activity, with 29,961 posts constituting approximately 37.7% of the annual total, and 36.2% of all posts during the study period, suggesting event- or campaign-driven engagement (**Fig. 2**). In November 2024, the number of posts was 9,988, whereas in December 2024 9,260 posts were recorded, collectively comprising approximately 25.4% of the total posts. The remaining months exhibited significantly lower activity, with January 2023 and September 2023 being the least active, each contributing approximately 3,200-3,400 posts.

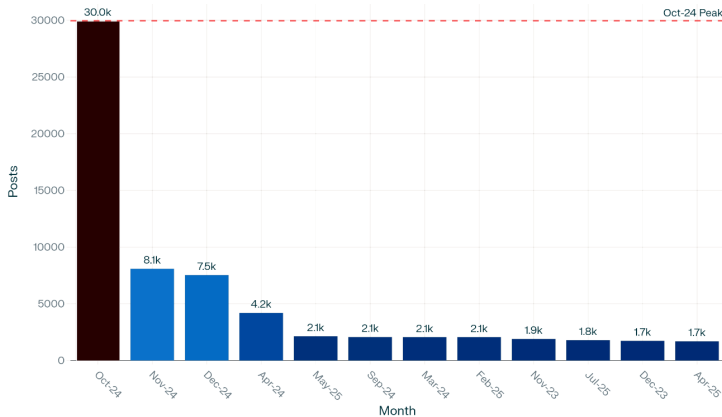


Fig. 2. Temporal distribution of posts by month (top 12 months by volume). A pronounced spike in posting activity occurred in October 2024, with 29,961 posts, representing 36.2% of all posts during the study period. This spike suggests event-driven or campaign-related activity during that month.

Hourly analysis indicated a substantial increase in activity, with 3,389 posts generated within a single hour, markedly exceeding the typical hourly averages. This escalation is likely attributable to promotional campaign efforts, dissemination of viral content, and responses to urgent information or news events.

The mean number of posts per day during the observation period was approximately 6.3, reflecting a generally consistent level of activity, with significant increases at specific intervals, particularly in October 2024.

#### Magnitude and significance of platform discourse

Over a two-year period, a total of 82,804 posts concerning nutraceutical products were identified on the X platform, authored by 61,527 users and generating 19,348,499 impressions. This data underscores the significant role of the X platform in the dissemination of dietary supplement information. With an average of 234 impressions per post, this information extends beyond the original network, indicating the potential for dissemination akin to mass media. This observation is consistent with the findings of *Matin et al. [2023]*, where #NutritionFacts tweets amassed over 50 million impressions over five years. The engagement pattern, characterised by an

average of 1.35 posts per user, suggests widespread casual participation rather than concentrated efforts by professional advocates. In the same context, Batheja *et al.* [2023] revealed that 26% of authors of precision nutrition-related tweets were experts in science or medicine, indicating that non-professional participants predominantly drive the discourse on nutraceuticals.

#### **Geographical patterns and market implications**

Posts originating from North America (59.96%) and South Asia (20.82%) illustrate the prevailing trends in the global dietary supplement industry. North America holds the largest market share, while the Asia-Pacific region, particularly India, exhibits rapid growth. The United States contributed 55.93% of the posts, attributable to its English-speaking population, high levels of supplement consumption, and advanced digital infrastructure. In 2024, the North American dietary supplement market was valued at USD 121.56 billion, representing 78.9% of the regional market share [Market Data Forecast 2025], which corresponds with the patterns observed in platform discourse. India's 20.01% share of posts signifies its emergence as a significant manufacturer and consumer market, bolstered by its English-speaking population and digital platform usage. The Indian nutraceutical market is expected to grow at a CAGR of 11.60% from 2025 to 2033, reaching USD 21.48 billion by 2033 [IMARC Group 2024], with digital penetration enhancing social media engagement. Lower engagement from European countries and the Japanese and Chinese markets suggests linguistic or platform differences, as these regions utilise platforms such as Douyin, Xiaohongshu, and Kuaishou [Marketing to China 2024, TMO Group 2025]. Regulatory frameworks influence promotional content, with European regulations necessitating premarket approval and maintaining positive ingredient lists, in contrast to U.S. post-market surveillance [Zovi *et al.* 2025], potentially affecting social media activity.

#### **Textual content patterns and discussion themes**

The terms “stem cells,” “peptides,” and “psychedelics” require interpretation within the context of post content. Their prominence indicates a convergence between nutraceutical marketing and cutting-edge biomedical themes, illustrating how scientific language is strategically employed to enhance the perceived sophistication and credibility of products. These terms commonly reference stem cell research, peptide-based supplements, and psychedelic substances in psychiatric research, reflecting discussions that extend beyond consumer health into broader scientific and biomedical discourse. Their frequent appearance may therefore reflect the increasing alignment of nutraceutical marketing with emerging biomedical technologies, including regenerative medicine and peptide-based therapeutics. References to “hazelnut,” “oil,” “sugar,” “palm,” and food companies show that posts focused on food industry topics and agricultural commodities, not just supplements. Nutraceutical search terms have captured discussions on foods with supplemental properties, aligning with the definition of nutraceuticals, including supplements and functional

foods. The frequent use of terms like “pharmaceuticals,” “pharma,” “manufacturing,” and “export,” alongside company references, highlights the role of the X platform in facilitating industry expert communication and health information dissemination. Hashtag analysis showed a high prevalence of manufacturing- and export-related tags, indicating that the platform serves as both a B2B networking tool and consumer health discussion forum.

#### **Nutraceutical product discussion emphasis**

The emphasis on specific compounds reflects prevailing market trends and consumer interests. The focus on CBD aligns with global fascination with cannabis-based products, despite regulatory uncertainties. Soleymannpour *et al.* [2021] analysed over two million CBD-related tweets, revealing that more than half were marketing-related, with pain, anxiety disorders, sleep disorders, and stress being the primary therapeutic claims. Li *et al.* [2023] demonstrated that CBD discussions vary by region, with Western platforms focusing on therapeutic effects while Asian platforms emphasize cosmetic applications. Similar trends were identified on Instagram, where the analysis of 1,466 posts with cannabinoid-related hashtags, including CBD, revealed a predominance of marketing and commercial content alongside posts sharing personal usage experiences, reflecting a high level of commercial interest [Litvinova *et al.* 2024]. However, in a later study on Instagram, 19.99% of posts were educational, providing scientifically informative content to users. The current work, frequent mentions of nattokinase and botanicals, such as turmeric and ashwagandha, indicate market expansion and shifting consumer preferences towards plant-based substances. The global nattokinase market, valued at USD 32.7 million in 2023, is projected to grow at a CAGR of 3.1% through 2030, driven by awareness of its cardiovascular benefits [Grand View Research 2024]. The turmeric supplement market has grown owing to the awareness of its anti-inflammatory benefits, with a rising demand for formulations with enhanced bioavailability [Verified Market Reports 2025]. Individual vitamins being less frequently discussed, despite their significant supplement sales, suggests they are often mentioned in broader terms like “supplements” or “vitamins.” This trend shows how newer compounds such as CBD and nattokinase are specifically identified, while established categories such as vitamins are generally referred to.

#### **Platform characteristics and communication patterns**

The distribution of followers among accounts reveals both influential creators and lesser-known users, enabling professional health communication and peer-level information sharing. Similar global patterns of concentrated but diverse participation have been reported in other hashtag-based studies, for example, with a focus on #physiotherapy, which revealed comparable user engagement dynamics and informational amplification on X [Mondal *et al.* 2024]. The high proportion of accounts with 100-1000 followers (47.42%) indicates that the participants were primarily micro-influencers and active community members. This aligns with

research showing that individuals with smaller but engaged audiences wield influence through authenticity rather than institutional authority [Kaňková *et al.* 2024]. Flaherty and Mangan [2025] found that micro-influencers achieve higher engagement rates than celebrity influencers or healthcare spokespersons. The prevalence of posts with hashtags related to manufacturing, exports, and companies indicates that X functions both as a business communication tool for the nutraceutical industry and as a source of consumer health information. This dual role requires an understanding of content trends, as industry discussions may dominate in certain periods, while consumer conversations predominate in others.

#### **Temporal dynamics and potential drivers**

In October 2024, there was a notable increase in posting activities, comprising 38% of all posts in the two-year period. This suggests that a particular event or campaign may have catalysed heightened discussions about nutraceuticals on the platform. Factors contributing to this surge may include industry conferences, regulatory updates, viral marketing initiatives, and media focus on nutraceutical topics. A manual review indicated that the sharp rise in nutraceutical discussions in October 2024 was precipitated by a widely publicised statement from a prominent U.S. figure that challenged regulatory norms and advocated for alternative health practices. Key industry conferences during this period, such as CPHI Milan (October 8-10), the Council for Responsible Nutrition (CRN) CONVERGENCE conference in Salt Lake City (October 9-11), and SupplySide West in Las Vegas (October 28-November 1) may have also influenced these discussions. Moreover, the overlap between the autumn wellness season and winter illness prevention may have contributed to the increased conversations related to supplements. Seasonal demand trends indicate that immune-support products, such as vitamin C, zinc, and elderberry, experience sales increases of 200-300% during the autumn and winter months [Crescent Edge Consulting2025], likely leading to more social media discussions as consumers seek information about seasonal health.

#### **Implications for information quality and consumer protection**

The discourse surrounding nutraceuticals on the X platform and inconsistent health information on social media presents challenges for consumers, health care professionals, and regulators. Alammari *et al.* [2025] conducted an analysis of nutrition-related tweets from Saudi health organizations and found that while 84% were accurate, only 4% included referenced evidence, highlighting challenges of evidence-based communication. Research on nutrition information in X revealed that lower-quality nutrition articles were more likely to be retweeted, suggesting that engagement metrics do not correlate with information quality [Ellis *et al.* 2025]. The mix of industry and manufacturer content, along with consumer discussions, creates diverse information, requiring consumers to distinguish between evidence-based health information and promotional content. Batheja *et al.* [2023] identified that

14.9% of precision nutrition tweets contained false information, with nutrigenomics concepts particularly susceptible to misinformation, highlighting the need for enhanced health literacy. The predominance of manufacturing and business content indicates that regulatory oversight should address both consumer-targeted health claims and professional communication. Misinformation on social media can lead to poor health decisions, decreased medication adherence, and diminished trust in health institutions [Sathianathan *et al.* 2025, Suarez-Lledo and Alvarez-Galvez, 2021]. Although governmental regulation of social media health content encounters constitutional challenges [Wu and McCormick 2018], combining platform moderation, healthcare professional involvement, fact-checking initiatives, and enhanced public health literacy is essential to combat misinformation [Kington *et al.* 2021]. The Federal Trade Commission (FTC) and the Food and Drug Administration (FDA) oversee dietary supplement advertising in the United States; however, enforcement on social media platforms remains challenging [Federal Trade Commission 2022]. With over 50% of X users contacting brands for customer care and 64% preferring social media over phone communication [Khoros 2020], healthcare organisations and supplement manufacturers must prioritise evidence-based communications to maintain public trust.

#### **Limitations and future research directions**

However, several methodological limitations of this study warrant further investigation. The analysis was confined to X platform content, excluding other social media platforms such as Instagram, TikTok, Facebook, and YouTube, which likely host supplementary discussions with unique patterns. A cross-platform analysis would provide a better understanding of digital supplement discourse. This study focused on term frequency without assessing the accuracy or quality of health claims. Future analyses using validated tools would help identify patterns in information quality and misinformation. Sentiment analysis was not conducted, limiting the understanding of whether the discussions were positive endorsements, consumer concerns, or regulatory criticism. The analysis used unverified self-reported location data, potentially causing geographic misclassification. The increased activity in October 2024 requires an analysis of specific posts and related events to understand temporal patterns. The study did not explore the connections between posting activity and market elements, such as product sales, stock prices, or media coverage. Future research should address (1) multi-platform analysis of supplement discussions, (2) evaluation of content quality and scientific substantiation, (3) comparison with pharmaceutical product discussions, (4) network analysis of influence relationships, (5) investigation of bot activity and automated promotion, (6) analysis of how regulatory announcements and research publications affect discussion patterns, and (7) research on how consumers use social media information for supplement-related decisions.

## **Conclusions**

This comprehensive analysis of posts on the X platform containing nutraceutical-related terminology revealed a substantial global discourse on dietary supplements, with 82,804 posts reaching an audience of approximately 19.3 million. The study shows that discussions about nutraceuticals on X have extensive reach worldwide, with concentration in North America and India, reflecting market trends and internet usage patterns. The content analysis identified diverse topics across supplement categories, from vitamins and minerals to newer compounds or proteins, such as cannabidiol and nattokinase, and traditional botanicals, such as turmeric and ashwagandha. Business-related discussions alongside consumer health information indicate that X serves multiple communication roles for stakeholders in the nutraceutical industry. With an average of 234 impressions per post, X served as a crucial medium for disseminating supplementary information. This has public health implications and requires efforts to ensure information quality, monitor misinformation, and develop evidence-based communication strategies to address supplement efficacy, safety, and regulatory concerns. These findings provide a foundation for future research on supplement discussions, information quality patterns, and the relationship between social media conversations and consumer purchasing behaviour. Understanding digital health communication patterns is essential for public health monitoring and evidence-based communication.

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## **Conflict of interest**

The authors declare no conflicts of interest.

## **Author contributions**

TPI and AGA conceived the study. AGA, ZM, and YH performed data collection and analysis. TPI, SPS, and DCD drafted the manuscript. All other authors provided review and editing support for this manuscript. TPI and SPS have contributed equally to this project and should be treated as First Authors. All authors critically reviewed and revised the manuscript and approved its submission for publication in the journal *Animal Science Papers and Reports*.

### Data availability

Raw datasets analysed during this investigation were derived from the public social media platform X (<https://x.com/>) and accessed through Fedica platform analytics (<https://fedica.com/>). Processed datasets compiled during the analysis are available from the corresponding author upon request, subject to ethical and privacy considerations.

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